USDA
United States Department of Agriculture
Forest Service
Rocky Mountain Research Station
Research Note RMRS-RN-40
July 2009

Mountain Pine Beetle-Killed Trees as Snags in Black Hills Ponderosa Pine Stands

J. M. Schmid[1], S. A. Mata[2], and W. C. Schaupp[3], Jr.

Abstract—Mountain pine beetle-killed ponderosa pine trees in three stands of different stocking levels near Bear Mountain in the Black Hills National Forest were surveyed over a 5-year period to determine how long they persisted as unbroken snags. Rate of breakage varied during the first 5 years after MPB infestation: only one tree broke during the first 2 years in the three stands; breakage increased during the third year; the highest percentage of snags broke during the fourth year; and 10% to 14% broke in the fifth year. Cumulatively, snag breakage was 76%, 91%, and 95% in a GSL 80/90, GSL 100/110, and unmanaged stand, respectively. On average, 56% of the snags broke below 25 ft. The rate and height of breakage in mountain pine beetle-killed trees indicates that they are unlikely to persist as suitable snags for more than 5 to 10 years after infestation.

Introduction

Tree mortality caused by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) has been extensive in ponderosa pine (*Pinus ponderosa* Lawson) stands in the Black Hills. Millions of ponderosa pine (PP) trees have been killed on the Black Hills National Forest (BHNF) by the mountain pine beetle (MPB) during the past century. During the last decade, the current MPB epidemic has killed over a million trees with annual mortality exceeding 300,000 trees per year in 2001 and 2002 (see Johnson and Long 2003). In the Beaver Park area southwest of Sturgis, SD, MPB-caused tree mortality was 100% in some stands (Allen and others 2002). In the vicinity of Deerfield Lake, tree mortality averaged 24 trees/acre (Allen and others 2003). As a result of this recent MPB-caused mortality, the number of snags has greatly increased on the BHNF (BHNF 2005).

Snags have been identified as an important component of PP stands because they provide essential habitat for a variety of animals. In order to maintain this important component, the 1997 BHNF Plan stipulates that, on average, three hard snags with diameters >9 inches at breast height (DBHs) and heights of $\geq$25 ft be maintained across each coniferous acre of the BHNF. The BHNF considers hard snags to be standing dead trees with branches and bark mostly intact. The Final Environmental Impact Statement (FEIS) of the Phase II amendment for the 1997 BHNF Plan indicates that this objective of three hard snags/acre with an average height of 25 ft is currently being met and is likely to be achieved in the future (BHNF 2005).

The FEIS does not indicate the primary source of snags or if unharvested MPB-killed trees (hereafter called MPB snags) will be left to function as snags. Presumably, MPB snags could be a primary source of snags and would be created by non-management activities. If MPB snags are left to fulfill the three snags/acre objective during the next 50 to 100 years, then information on their persistence is critical to achieving that objective. However, persistence of MPB snags in PP stands on the BHNF is imprecisely known. Further, although Lentile and others (2000) reported the median persistence of snags on the BHNF was 15 years, their report did not identify if their median snag persistence represents the persistence of snags created by a combination of different factors (e.g., lightning, MPB-killed, wet snowstorms/wind, and other factors) or snags primarily created by a single factor (e.g., lightning).

While information on the persistence of MPB snags is lacking for the Black Hills, data are available from other states and Canadian provinces (see Lewis and

Schmid, J.M.; Mata, S.A.; Schaupp, W.C., Jr. 2009. **Mountain pine beetle-killed trees as snags in Black Hills ponderosa pine stands.** Res. Note RMRS-RN-40. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 5 p.

Authors

[1] Retired entomologist, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

[2] Retired entomologist, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

[3] Entomologist, U.S. Forest Service, Forest Health Protection, Rapid City, SD.

Hartley 2006). In Colorado PP stands, MPB snags began falling during the third year after infestation at one location and during the fourth year at a second location (Schmid and others 1985). Once trees started falling, the rate of falling during the following 4 years was 3 to 4% per year at one location and 17% per year at the other location (Schmid and others 1985). Considering both locations, 60 to 70% of the trees fell during the 10-year period after infestation.

Realizing that snag persistence may vary by source as well as site conditions, persistence of MPB snags on the BHNF becomes important if MPB-killed trees are left as snags to fulfill the snag objective of the BHNF Forest Plan. This study determined the persistence of MPB snags (their rate of breakage) and height at which breakage occurred at one location during the 5 years following MPB attack.

Study Area

In 1986, a set of four 2.5-acre permanent plots was established about 0.5 miles southwest of the Bear Mountain Lookout in the BHNF; the lookout is northwest of Custer, SD. The plots are located near the bottom of a west-facing slope in pure PP stands. Other tree species are present in the vicinity of the plots, but were not present on the plots.

Plots were established to study the relationship between MPB-caused PP mortality and stand density. The plots consisted of one uncut control representing the unmanaged stand condition and three plots cut to growing stock levels (GSLs) of 60, 80, and 100. In 2000, the partially cut plots were cut again, at which time, the GSL of each plot was increased by 10 ft^2/acre. Prior to partial cutting, basal areas in the plots ranged from 143 to 162 ft^2/acre and quadratic mean diameters ranged from 10 to 11 inches. The plots would have been classified in structural stage (SS) 4C prior to cutting. After cutting, the GSL 80/90 would have been classified as SS4B while the GSL 100/110 and unmanaged stand would remain in SS4C. Trees within the central half of each plot (central inventory plot, or CIP) were tagged in order to determine growth and tree mortality in subsequent years.

During the first 10 years following partial cutting in 1987, MPB-caused mortality was limited to 1 tree in each of the GSL 60/70 and GSL 80/90 plots and a group of six trees in the buffer strips of the unmanaged plot in 1991 and 1993. In 1998, the MPB population increased both in the plots and general area surrounding the plots. During the next 6 years, the epidemic MPB population killed hundreds of trees. More than 200 trees were attacked within the CIP, ca. 1.25 acres, of the control plot in 2003. Adjacent partially cut plots also incurred substantial MPB-caused mortality in 2002, 2003, as well as in later years (see Schmid and others 2007).

Methods

To determine the rate of breakage[1] and height of breakage for the MPB snags, MPB snags were monitored in the CIPs of the GSL 80/90, 100/110, and the unmanaged stand. We monitored 29 MPB snags in the GSL 80/90, 56 MPB snags in the GSL 100/110, and 192 MPB snags in the unmanaged stand. MPB snags in the GSL 80/90 were created in 2002; those in the GSL 100/110 and unmanaged stand were created in 2003.

The trees were surveyed on September 29, 2004; May 19 and September 16, 2005; April 11 and September 15, 2006; April 21 and August 30, 2007; and April 21 and September 24, 2008. Fall surveys were generally conducted in September because each subsequent September represented approximately one or multiple years since the probable completion of the MPB attack period. Trees were also surveyed in the spring (April or May) of each subsequent year to determine if breakage was occurring more frequently during the September-April period than in the April-September period.

The point at which trunk breakage occurred was measured from ground level to 8 ft above ground but was estimated for heights >8 ft. During analysis, height of breakage for each tree was assigned to one of the following categories: 0-2 ft, 3-15 ft, 16-24 ft, 25-35 ft, or ≥36 ft. These categories were developed in collaboration with Blaine Cook, Silviculturist, BHNF.

The results of the surveys are presented in terms of years since the trees were attacked rather than the date on which surveys were conducted. For example, the results for September 2004 represent 1 year after attack for the GSL 100/110. The percentage of trees with stem breakage for any specific date/year represents the number of MPB snags exhibiting breakage between the previous survey and the successive survey divided by total number of MPB snags in the sample. Cumulative percentages were derived by adding percentages for successive surveys.

Tree diameters for the year of MPB attack were based on previous diameter measurements and growth rates derived from those measurements. Trees were measured in 1987 and 1997. The annual diameter

[1] It became obvious in the third year of the study that MPB snags were breaking off at various heights above ground and were not always breaking off at ground level (i.e., completely falling). Thus, "rate of breakage" is used rather than "rate of falling" because some portion of the bole remained standing after an upper portion broke off.

growth rate for each tree derived from these measurements was multiplied by the number of years between the year of attack and the 1997 measurement. This value was added to the 1997 diameter to derive the diameter during the year of attack.

Results and Discussion

Rate of Breakage

GSL 80/90

No MPB snags had breakage during year 1 (table 1). One MPB snag broke during each of the next 2 years (years 2 and 3), or 3% of the MPB snags in each year (table 1). Sixteen MPB snags (55%) broke during year 4. During year 5, four (14%) MPB snags broke. Cumulatively, 76% of the MPB snags had breakage in the 5 years following MPB attack.

GSL 100/110

No MPB snags had breakage during years 1 and 2 (table 1). Eighteen MPB snags (32%) had stem breakage during year 3. During years 4 and 5, 25 MPB snags (45%) and eight MPB snags (14%) suffered breakage, respectively. Cumulatively, 91% of the MPB snags had breakage within the 5-year period following MPB attack (table 1).

Unmanaged stand

No MPB snags had breakage during the first 2 years (table 1). Forty-six MPB snags (24%) had stem breakage during year 3. During years 4 and 5, 117 MPB snags (61%) and 19 MPB snags (10%) suffered breakage, respectively. Cumulatively, 95% of the MPB snags broke during the first 5 years following MPB attack (table 1).

Period of Breakage

Breakage was slightly greater in the September-April period (54%) than in the April-September period (46%) during year 3. During year 4, 92 (78%) MPB snags broke in the September-April period while 25 (22%) broke in the April-September period. All the MPB snags breaking in year 5 broke in the September-April period. Cumulatively, 75% of the MPB snags broke during the September-April period.

The percentage of MPB snags breaking was highest between September 2006 and August 2007 (table 1, year 4). High westerly winds occurred in the Bear Mountain area in September 2006 immediately following the September survey (J. Schmid, pers. obs. 2006), and 30 to 65 mph winds were present throughout the BHNF on March 2, 2007 (B. Cook, pers. comm. 2007). Winds of these magnitudes undoubtedly contributed to greater rates of breakage during this period.

Direction of Fall

Most MPB snags breaking within 1 ft above ground fell in an easterly and southerly direction—mostly uphill or across the slope. Because the study area was located at the bottom of a predominantly west-facing slope, the trees were more exposed to westerly and northerly winds and mostly protected from southerly and easterly winds. Thus, the previously mentioned westerly and, to a lesser extent, northerly winds exerted more influence on the direction of fall and probably caused the observed pattern of falling.

Height of Breakage

Height of breakage in all three stands ranged from near ground level (<1 ft) to ≥36 ft (table 2). More MPB snags broke off between 0 and 2 ft above ground level than in any other height category (table 2). Breakage between 0 and 2 ft was partially attributed to the presence of red belt fungus (*Fomitopsis pinicola* (Swartz:Fr) Karst) as evidenced by conks of this fungus on the basal section of numerous trees. MPB snag breakage was also high in the 25- to 34-ft category. Breakage above 15 ft may have been influenced by the pouch fungus (*Cryptoporus volvatus* (Pk.) Shear) that was visible on a few snags. The presence/absence of this fungus was not confirmed on all snags because the snags were not felled for more thorough examination.

Table 1. Number, percent, and cumulative percentage of breakage in MPB snags by GSL and year since MPB attack.

	GSL 80/90 (SS4B)			GSL 100/110 (SS4C)			Unmanaged stand (SS4C)		
Year	Number	Percent	Cum. %	Number	Percent	Cum. %	Number	Percent	Cum. %
1	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
2	1	3.4	3.4	0	0.0	0.0	0	0.0	0.0
3	1	3.4	6.8	18	32.1	32.1	46	24.0	24.0
4	16	55.2	62.0	25	44.6	76.7	117	60.9	84.9
5	4	13.8	75.8	8	14.3	91.0	19	9.9	94.8

Table 2. Percentage of MPB snags breaking at various heights in the GSL 80/90, 100/110, and unmanaged stand. Percentages are rounded to nearest whole number.

Height above ground	GSL 80/90 (SS4B)		GSL 100/110 (SS4C)		Unmanaged stand (SS4C)	
	Number	Percent	Number	Percent	Number	Percent
0-2 ft	8	28	28	50	81	42
3-15 ft	6	21	3	5	19	10
16-24 ft	0	0	3	5	13	7
25-35 ft	7	24	14	25	42	22
≥36 ft	2	7	3	5	27	14
Unbroken	6		5		10	

GSL 80/90

The MPB snag in year 2 broke off above 25 ft while the MPB snag in year 3 broke off below 25 ft. In year 4, 57% of MPB snags broke off below 25 ft. Fifty percent of the snags breaking in year 5 broke off below 25 ft. Cumulatively, 49% of broken MPB snags initially broke below 25 ft (table 2). Two of the snags initially breaking above 25 ft later broke below 25 ft.

GSL 100/110

Height of breakage varied from years 3 to 5. In year 3, 44% of MPB snags broke below 25 ft. In years 4 and 5, 92% and 38% broke below 25 ft, respectively. Cumulatively, 61% of the broken MPB snags on the GSL 100/110 plot broke below 25 ft (table 2).

Unmanaged stand

As in the GSL 100/110 stand, height of breakage varied from years 3 to 5. In year 3, 33% of MPB snags broke below 25 ft. In years 4 and 5, 74% and 63% broke below 25 ft, respectively. Cumulatively, 59% of the broken MPB snags broke below 25 ft (table 2). Three snags initially breaking above 25 ft broke below 25 ft within 1 year of the initial break.

Conditions Relating to Rate of Breakage

Some larger MPB snags toppled other MPB snags and one uninfested PP sapling as they fell. Whether the other MPB snags would have fallen at the same time if they had not been hit by the falling snags was not determined.

The percentage of broken MPB snags was lowest in the GSL 80/90 and highest in the unmanaged stand. While this suggests MPB snag breakage may be correlated with stand density, the small number of samples in the GSL 80/90 precludes a definite conclusion with respect to stand density. Trees that are well-spaced with diameter growth >1 inch/10 years may be less subject to breakage.

Diameters of MPB snags standing after 5 years ranged from 8 to 14 inches. In the GSL 80/90, diameters ranged from 10 to 14 inches with 17% of the standing MPB snags <11 inches. In the GSL 100/110, diameters ranged from 9 to 13 inches with 55% of the standing snags <11 inches. In the unmanaged stand, diameters ranged from 8 to 14 inches with 80% of the standing snags <11 inches. MPB snags >11 inches may be more prone to early breakage than smaller MPB snags but growth prior to MPB infestation may also contribute to persistence.

Management Implications

During the field inventory work, this study was unaware of the BHNF's classification of snags as hard or soft snags and was primarily intent on determining how long MPB snags remained standing. Thus, MPB snags were not classified as hard or soft snags. In retrospect consideration of the criteria for hard and soft snags, classification of MPB snags into either category would have been ambiguous because the MPB snags exhibited characteristics of both categories during the 5 years. Bark sloughing was not evident on nearly all MPB snags after 5 years which classifies the MPB snags as hard snags. The presence of bole breakage on a high percentage of the MPB snags indicates some decay, which would classify the trees as soft snags. Because of these ambiguities, MPB snags could, at best, be classified as hard snags during the first 2 to 3 years and as soft snags thereafter.

Given the prior considerations, MPB snags would be a poor choice for fulfilling the hard snag objective in the BHNF Forest Plan if MPB snags throughout the BHNF exhibit the same patterns for rate of breakage and height of breakage as recorded in this study. Assuming 90 to 95% of MPB snags in unmanaged stands exhibit breakage within 5 years of MPB attack (fig. 1) and about 60% of the breakage occurs below

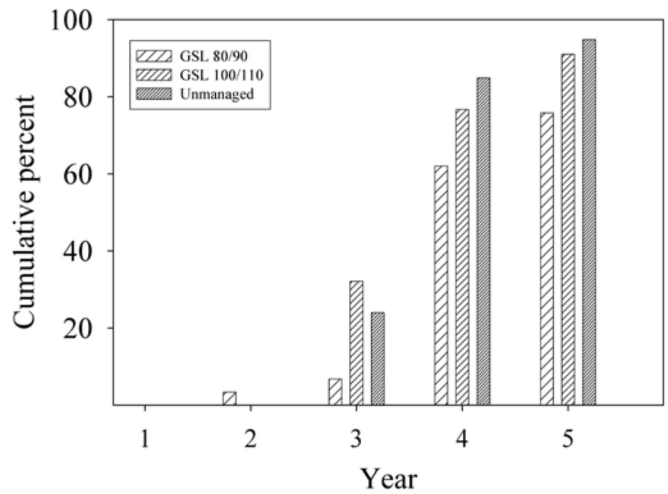

Figure 1. Cumulative percentages of MPB snags breaking during the 5 years following MPB infestation.

25 ft, then approximately two of every three MPB snags left per acre would not satisfy the BHNF snag criteria 5 years after MPB infestation. The remaining MPB snag would probably be unsuitable on most acres because it would probably break below 25 ft in subsequent years. In order to have three functional, unbroken MPB snags/acre after 5 years, 30 MPB snags/acre would have to be left on each acre. Although some of the broken MPB snags would still satisfy the BHNF criteria because they broke above 25 ft, it seems doubtful that they would remain standing in light of observed subsequent breakage in previously broken snags and the probability of strong winds in any given year. Any unbroken MPB snags remaining after 5 years would probably be unsuitable 5 years hence (i.e., 10 years after MPB attack).

If the assumed median age for snags in the Black Hills is 15 years (Lentile and others 2000), then MPB snags would generally not be expected to persist for 15 years. Under a 30-year reentry cycle, at least 30 MPB snags would probably have to be created every 10 years in order to maintain the three snags/acre objective for 30 years. This scenario seems unlikely if the BHNF manages PP stands to minimize MPB-caused mortality.

The rates of breakage observed at this study site may not be applicable to all sites or stands on the BHNF. Rates of breakage observed in this study contrast sharply with the results from the Colorado study wherein 60 to 70% of MPB snags in PP fell within 10 years after attack. The difference may be attributable to site differences. The Colorado sites were generally dry with little ground cover, whereas the generally moister Black Hills site supported understory grasses and some shrubs. In addition, this Black Hills site was exposed to westerly and northerly winds that may have increased breakage. Thus, the particular site conditions for this location may have contributed to greater rates of breakage than would generally be observed in other drier sites in the BHNF.

Some readers might interpret our statements regarding the creation of MPB snags as advocating the use of MPB baits or other means to induce MPB attacks in specific stands in order to meet the snags/acre criteria. To the contrary; we do not advocate such management activities. This study was undertaken solely to determine the suitability of MPB-killed trees as potential snags so that the BHNF might consider using them to fulfill the snags/acre criteria.

MPB snags observed in this study were created by an MPB epidemic that created large groups of MPB snags. Under these conditions and patterns of breakage, MPB-killed trees would be better harvested than left as snags. Although it seems doubtful, MPB snags created under endemic MPB populations may persist longer and thus be more suitable for meeting snag criteria. However, the longevity of MPB snags created by endemic MPB populations is unknown and needs to be determined.

Literature Cited

Allen, K.K.; Schaupp, W.C., Jr.; Long, D.F. 2002. Evaluation of mountain pine beetle activity in the Beaver Park area of the Black Hills National Forest. Biological Evaluation R2-03-09. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Renewable Resources, Forest Health Management. 14 p.

Allen, K.K.; Schaupp, W.C., Jr.; Long, D.F. 2003. Evaluation of mountain pine beetle activity in the Deerfield area of the Black Hills National Forest. Biological Evaluation R2-03-04. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Renewable Resources, Forest Health Management. 14 p.

Black Hills National Forest. 2005. Black Hills National Forest Phase II Amendment: Final Environmental Impact Statement for the 1997 Land and Resource Management Plan. Custer, SD: U.S. Department of Agriculture, Forest Service, Black Hills National Forest. 470 p. plus appendices.

Cook, B. 2007. Personal communication. Email dated March 6, 2007. Silviculturist, U.S. Forest Service, Black Hills National Forest.

Johnson, E.; Long, D.F. 2003. [Letter to Forest Supervisor]. January 7, 2003. 3 p. On file at: U.S. Department of Agriculture, Forest Service, Black Hills National Forest, Custer, SD.

Lentile, L.; Smith, F.W.; Shepperd, W.D. 2000. Snag management in the Black Hills National Forest. Unpublished final report submitted to the Black Hills National Forest. 27 p.

Lewis, K.J.; Hartley, I.D. 2006. Rate of deterioration, degrade, and fall of trees killed by mountain pine beetle. BC Journal of Ecosystems and Management 7(2): 11-19.

Schmid, J.M. 2006. Personal observation. October 4, 2006. Retired entomologist, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Schmid, J.M.; Mata, S.A.; McCambridge, W.F. 1985. Natural falling of beetle-killed ponderosa pine. Res. Note RM-454. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p.

Schmid, J.M.; Mata, S.A.; Kessler, R.R.; Popp, J.B. 2007. The influence of partial cutting on mountain pine beetle-caused tree mortality in Black Hills ponderosa pine stands. Res. Pap. RMRS-RP-68. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 19 p.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and series number.

Fort Collins Service Center

Telephone	(970) 498-1392
FAX	(970) 498-1122
E-mail	rschneider@fs.fed.us
Web site	http://www.fs.fed.us/rm/publications
Mailing address	Publications Distribution Rocky Mountain Research Station 240 West Prospect Road Fort Collins, CO 80526

Rocky Mountain Research Station
240 W. Prospect Road
Fort Collins, Colorado 80526

Rocky Mountain Research Station

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of the National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals. Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Station Headquarters
Rocky Mountain Research Station
240 W Prospect Road
Fort Collins, CO 80526
(970) 498-1100

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana

Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah

Federal Recycling Program Printed on Recycled Paper